

FA 8.2 EVOLUTION OF SOIL MOISTURE AND TEMPERATURE IN THE MAPS/RUC ASSIMILATION CYCLE

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1. INTRODUCTION

A simple soil/vegetation scheme has been incorporated into the three-dimensional isentropic-sigma model used as a forecast component of a new (40-km) version of the MAPS (Mesoscale Analysis and Prediction System, Benjamin *et al.* 1996) four-dimensional data assimilation system. (MAPS is implemented at the National Centers for Environmental Prediction (NCEP) as the Rapid Update Cycle or RUC.) Our motivation is to improve MAPS predictions of surface fluxes and atmospheric boundary-layer properties by explicitly predicting soil moisture (and temperature) in a data assimilation cycle over a period of months to years rather than depending on climatological soil moisture values, which can be seriously in error during and after dry or rainy periods. The soil model contains heat and moisture transfer equations together with the energy and moisture budget equations on the ground surface, and uses an implicit scheme for the computation of the surface fluxes. The heat and moisture budgets are applied to a thin layer spanning the ground surface and including both the soil and the atmosphere with corresponding heat capacities and densities. A concept for treating the evapotranspiration process, developed by Pan and Mahrt (1987), is implemented in the MAPS soil/vegetation scheme.

2. INCORPORATION INTO 3-D MODEL

Based on one-dimensional testing of the MAPS soil model, a 5-level (0,5,20,40 and 150 cm) version has been incorporated into the MAPS model using the Clapp-Hornberger (1978) parameterization of soil water properties with fitting parameters from Cosby *et al.* (1984). Global datasets of soil type, vegetation type, vegetation fraction, albedo and deep soil temperature with 1 degree resolution (obtained from NCEP) were interpolated to the MAPS 40-km grid with application of a land-water mask for better representation of the coast line. Fig-

ure 1 depicts the climatological August vegetation fraction field, which varies from desert areas in the southwest to well-vegetated areas along the Pacific Northwest coast and in the Northeast.

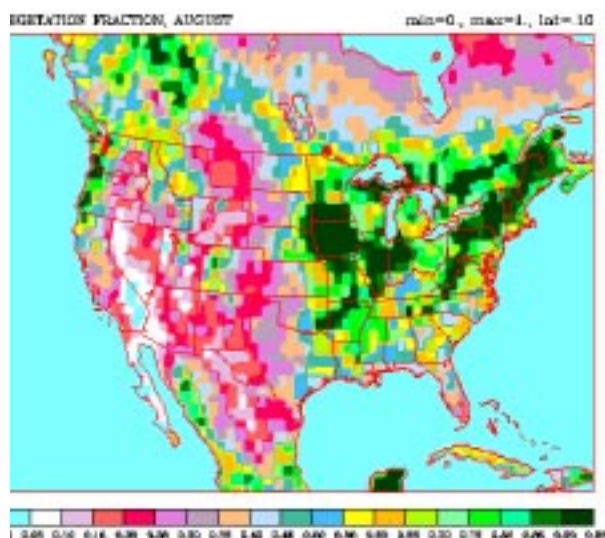


Figure 1. Vegetation fraction for August in 40-km MAPS grid.

On 26 April 1996, the multilevel soil/vegetation model was introduced into the continuously running MAPS assimilation system. It was first necessary to initialize the fields of soil temperature and moisture. For temperature, a linear variation with depth was assumed between the analyzed value at the lowest atmospheric model level (10 m above ground) applied at the top level in the soil and a modified field of deep soil temperature as obtained from NCEP. For moisture, a linear change with depth was assumed between a top-level value based on fields of climatological moisture availability used by older versions of MAPS and a field capacity value assumed at the lowest model level (1.5 m in the 3-D model). Since 26 April 1996, the soil

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temperature and volumetric water content fields, as predicted by the soil model, have been allowed to evolve in the MAPS 3-hourly assimilation cycle. Because there is not yet a high-frequency, national domain precipitation analysis available in real time, it is necessary to depend on the MAPS 3-hourly precipitation forecasts for precipitation input. Lack of actual precipitation data and soil moisture information in real time implies that the predicted soil fields, particularly deep soil moisture, are vulnerable to “model drift.” This potential model drift could result from either inaccurate precipitation input or from deficiencies in the soil model itself or in soil properties that it uses. For this reason, it is important to undertake verification of soil moisture fields and to correct the bias in the areas where it exists.

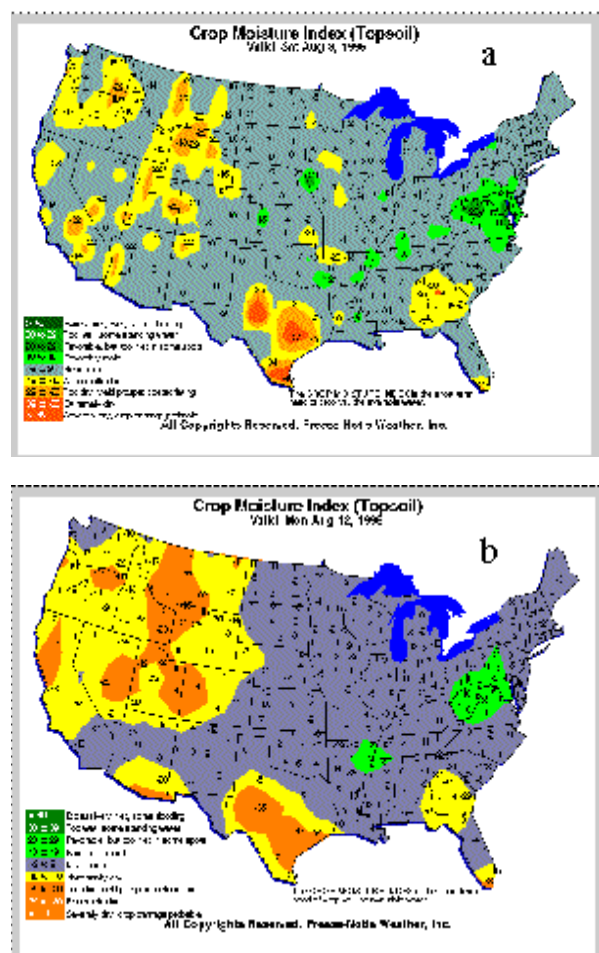


Figure 2. Crop moisture index for 3 August (a) and 12 August (b) 1996.

The information about actual values of volumetric or gravimetric soil moisture is very limited; therefore, it is a real problem to verify the MAPS evolved soil moisture fields. However, agrometeorological data related to soil moisture can be used for at least qualitative comparisons. One type of agrometeorological data is the crop moisture index (CMI) available over the United States on a weekly basis. The CMI is designed to evaluate short-term soil moisture conditions across major crop producing regions and is based on the mean air temperature and precipitation for each week. The most appropriate field

to compare with CMI is volumetric soil moisture content in the top layer of the MAPS soil domain, which has the most rapid response to recent precipitation events and other changes in surface conditions. In particular, it appears useful to compare the *tendencies* in the CMI and top soil moisture fields. Figure 2 (a,b) shows the evolution of CMI during 9 days in August. The western and central parts of the United States are drying out, a dry area in Texas is expanding, and the area of excessive soil moisture remains in the mid-Atlantic states. Similar trends can be traced in the evolution of MAPS/RUC soil moisture from the upper layers (Fig. 3 a,b). Dry areas became wider in the Pacific Northwest, California, southern Arizona and Texas, and the Atlantic Coast states are excessively wet.

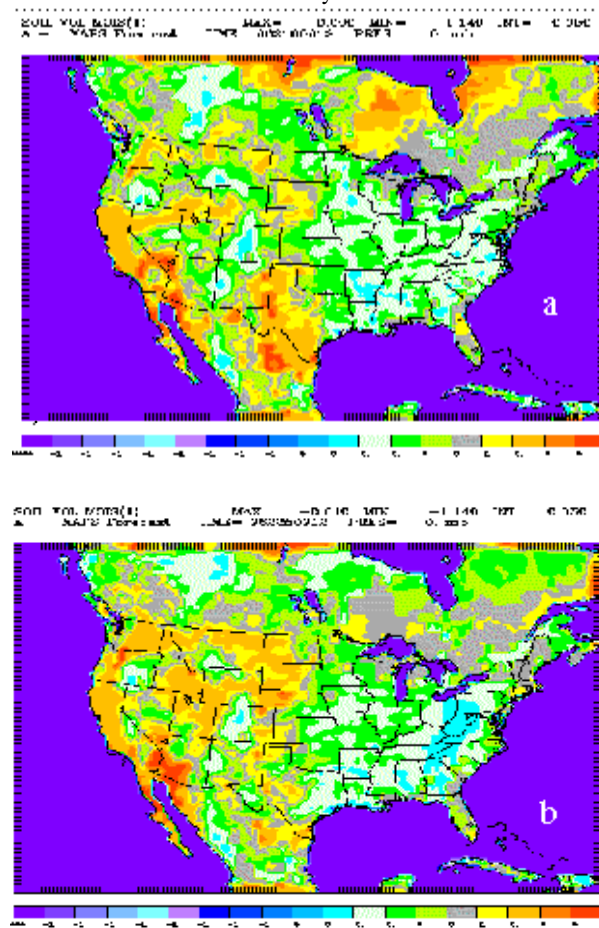


Figure 3. Volumetric soil moisture content in top 2.5 cm valid at 2100 UTC 3 August (a), and 2100 UTC 12 August (b).

Another source of information that may be used for verifying soil moisture and its vertical distribution is the student archive being developed by the Global Learning and Observations to Benefit the Environment (GLOBE) Program (Fullerton, 1995). This data set consists of environmental observations from around the world, including soil moisture measurements at four depths (10, 30, 60 and 90 cm; Colliander *et al.* 1996). Unfortunately, for the North American continent, soil moisture measurements are limited, but even these few measurements are useful to check against while waiting for data sets with better coverage.

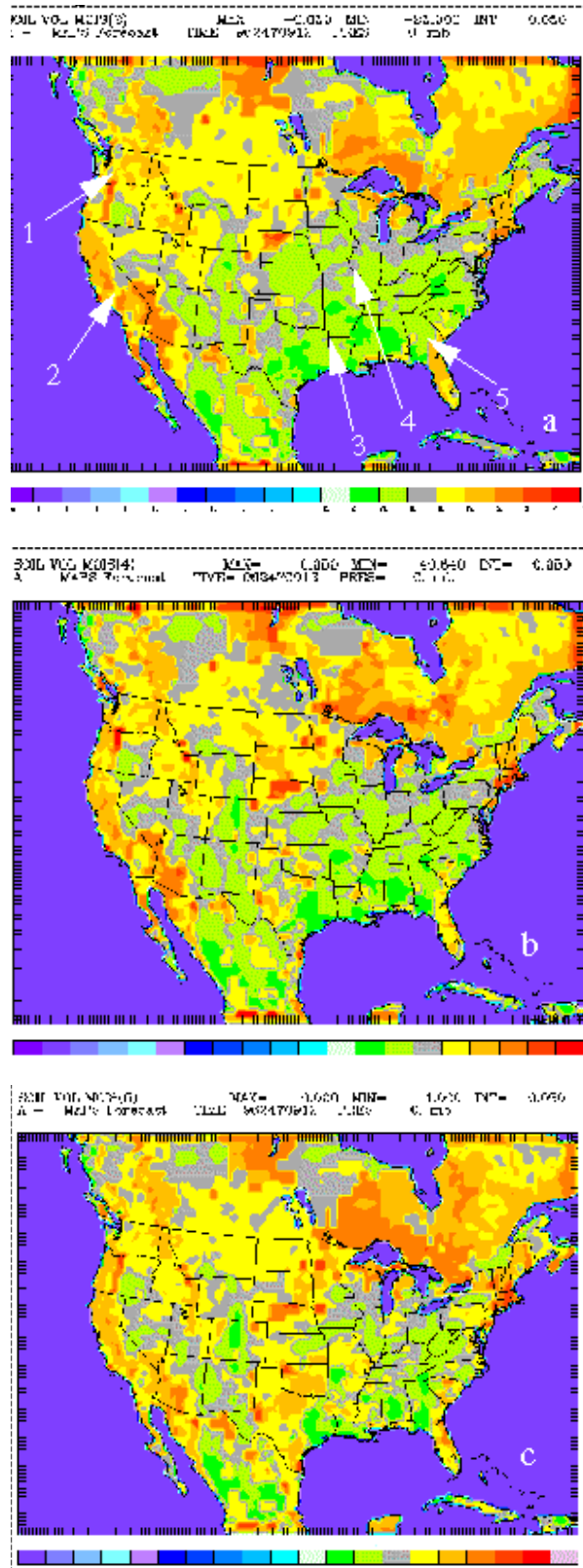


Figure 4. MAPS/RUC volumetric soil moisture fields at: (a) 5 cm depth, (b) 40 cm depth, and (c) 150 cm depth, valid at 2100 UTC 3 September 1996.

Figure 4 (a,b,c) is an example of volumetric soil moisture content at three depths (5, 40 and 150 cm) produced in the MAPS evolving 3-h cycle as of 3 September (cycled since 26 April 1996). Arrows with numbers from 1 to 6 show the location of observational points for this day in the GLOBE data set. The driest point observed on 3 September (Table 1) was from the San Joaquin Valley in California, showing a slight increase of moisture with depth. This station is in good agreement with the MAPS/RUC soil moisture field, where the area around station 2 is very dry at 5 cm depth and less dry at the bottom of soil domain. Station 3 is also consistent with the predicted soil moisture field, moderately wet in the upper layers and less moist toward the bottom. Stations 4 and 5 are also moderately wet, but with a slight increase of soil moisture with depth, and, despite the coarse scale of the display in Fig. 4, this tendency can be seen in the MAPS/RUC fields in the vicinity of these stations. Although the area in Washington surrounding Station 1 appears to be too dry after more than 4 months (at this writing) of application, the soil moisture fields look quite reasonable overall.

Table 1: Gravimetric soil moisture for 3 September 1996 from GLOBE student archive¹

Station	10cm	30cm	60cm	90cm
1	9.7%*	8.7%*	8.7%*	
2	0.0%	1.0%	4.2%	4.8%
3	8.0%	6.1%	7.2%	6.8%
4	5.6%*	6.1%*	7.5%*	8.7%*
5	7.0%	9.0%	9.2%	9.2%

*1. Values with * are transformed from meter readings to gravimetric soil moisture using calibration curve received from Dr. J. Washburne of the University of Arizona*

3. CONCLUDING REMARKS

Qualitative verification of soil moisture and temperature fields shows that these fields, in general, are quite realistic, except for several local problems that we have noticed. One of them is the relatively moist area in southeast Oregon. The crop moisture index for this region indicates that it is less dry than the rest of the state, but based on climatological considerations, we are fairly certain that it should not be as moist as the Midwest area. There are several aspects to this problem. Monitoring of precipitation revealed that a feedback has occurred in this area, with high soil moisture promoting excessive precipitation and vice versa. This area is one of the most data-sparse regions in the lower 48 United States with regard to surface observations, so there has been no way to correct excessive moisture in the surface layer in the MAPS atmospheric objective analyses. Thus, a local “model climate drift” appears to have occurred.

This problem also may be related to disregard of non-uniform vertical distribution of soil properties, and of different thicknesses of soils for different areas. As a result, the model can let an excessive volume of water infiltrate and stay in shallow soils. This appears to have occurred in southeast Oregon and some mountain regions in the western United States. While soil moisture may be too high in these areas because of incorrectly specified soil depth, precipitation is indeed larger over high terrain in the summer due to the diurnal convection cycle. There are likely soil depth errors of the opposite sign at other points in the MAPS domain, where greater thickness is needed than that defined in the model right now.

Despite these problems, utilizing cycled soil moisture and temperature fields instead of climatology in the MAPS/RUC system does not show negative impact overall on atmospheric boundary layer properties, and even allows improvements in the lower atmosphere.

4. REFERENCES

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